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# An Evidence-Based Evaluation of Speech Rate Treatments for Individuals with Parkinson's Disease

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## Abstract

Research confirms the long-standing clinical observation that Parkinson's disease patients exhibit wide variability in speech rate. Thus, modifying speech rate has been documented to be one of the most powerful treatment options for these patients. This review discusses several evidence-based rate control interventions for dysarthric speakers with Parkinson's disease. Studies discussed utilized various speech rate interventions, including pacing boards, alphabet board supplementation, visual and auditory feedback, cueing/pacing strategies, and delayed auditory feedback. Interventions discussed represent a hierarchy from "rigid" strategies, which impose maximal rate control, to techniques allowing for greater speech naturalness and independent rate control. All procedures are analyzed with respect to effectiveness in reducing rate, impact on intelligibility and prosody, cost, training requirements, specific alterations made to speech rate, and other relevant dimensions.

**Key Words:** Evidence-Based Practice, Parkinson's disease, hypokinetic dysarthria, speech rate, delayed auditory feedback

Research has confirmed the long-standing clinical observation that Parkinson's disease patients exhibit wide variability in speech rate, and a high prevalence of articulatory imprecision (e.g., Darley et al., 1975; Logemann, Fisher, Boshes & Blonsky, 1978; Trail, Fox, Ramig, Sapir, Howard, & Lai, 2005). Dysarthric speech is often associated with significant reductions in speech intelligibility; as such, modifying speech rate has been documented to be a powerful treatment strategy for dysarthric speech. Rate control interventions may increase articulatory precision, as well help to coordinate various speech processes. In addition, reduced speaking rate allows the listener more processing time to "fill in the gaps" when attempting to interpret a distorted speech signal. Due to articulatory distortions (i.e., "blurring") present in dysarthric speech, the listener's perception of phonemes becomes more difficult. Thus, speech rate is often judged to be faster than it actually is (Yorkston, Beukelman, Strand & Bell, 2000). Lastly, rate control techniques such as alphabet boards provide the listener with visual information to aid in comprehension of the message (Beukelman & Yorkston, 1977; Crow & Enderby, 1989).

Speech rate is generally thought to be "excessive" for a particular speaker when it is beyond the capabilities of that person's neuromuscular control system (Yorkston et al., 2000). For example, a patient may actually be speaking more slowly than unimpaired speakers, but may still be speaking at an excessive rate given his or her impairment, as well as the listener's processing abilities. Appropriate intervention may result in a further rate reduction (Yorkston et al., 2000). In such cases, the primary goal is not "normal" rate, but "compensated intelligibility." In other words, the key question is not how the speaker's rate compares to the normative value, but whether his or her speech can be made more intelligible and/or more "natural" by modifying rate (Yorkston, Beukelman & Bell, 1988). Therefore, several evidence-based interventions frequently used to accomplish these objectives will be discussed in this tutorial. First, however, brief reviews of Parkinson's disease and hypokinetic will be provided.

## Parkinson's Disease

Parkinson's disease (PD) is a degenerative disorder of the basal ganglia (and its control circuit) affecting motor control (Pinto, Ozsancak, Tripoliti, Thoboise, Limousin-Dowsey, & Auzou, 2004). Idiopathic Parkinson's disease, the most common type, occurs in about one percent of the U.S. population over 50 years of age, with approximately 40,000 new cases reported each year (Yorkston, 1996). The incidence of PD increases sharply after 64 years of age, and peaks between 75-84 years of age (Yorkston et al., 2000). Parkinson's disease is often divided into subgroups based on etiology and associated symptoms. The term idiopathic or primary Parkinson's disease is used when the cause of the disease cannot be identified. Secondary parkinsonism includes a number of disorders with "parkinsonian" features that have an identifiable etiology, such as toxicity, infections, neuroleptic drugs, TBI, or CVA. Lastly, "parkinsonism-plus" syndromes are conditions that include symptoms of PD as part of the clinical profile, such as progressive supranuclear palsy (PSP). As such syndromes result involve damage to multiple neural systems, they often produce dysarthria that is different from that associated with PD (Yorkston et al., 2000).

The motor symptoms associated with PD result from a loss of dopaminergic neurons in the basal ganglia, substantia nigra, and brainstem (Yorkston, 1996; Pinto et al., 2004). The disease usually involves a chemical imbalance between dopamine-activated and acetylcholine-activated neurons of the striatum (i.e., the caudate nucleus and the putamen) (Yorkston, Miller, & Strand, 1995). A neurologist's diagnosis of PD is usually based on the presence of resting tremor, rigidity, akinesia (i.e., lack of movement), and postural instability (Adams, 1997). The acronym TRAP (**T**remor, **R**igidity, **A**kinesia, and **P**ostural Instability) is often used as a mnemonic for these symptoms (Yorkston et al., 2000). Bradykinesia, a less extreme form of akinesia often seen in PD patients, refers to a slowness of volitional movements (Yorkston et al., 2000; Pinto et al., 2004). Secondary signs of PD include stooped posture, reduced arm swing, micrographia (i.e., small handwriting), and masked facial expression (Adams, 1994). In addition, approximately 15% of all PD patients meet the criteria for dementia (Levin, Tomer, & Rey, 1992).

## Hypokinetic Dysarthria

The term "dysarthria" actually refers to a *group* of speech disorders involving any or all of the basic motor speech processes (i.e., respiration, phonation, resonance, articulation, and prosody) resulting from disturbances in muscular control secondary to neurological damage (e.g., degenerative diseases, CVA, TBI, etc.). Dysarthria is typically characterized by some degree of weakness, slowness, incoordination, or alteration of muscle tone of the speech apparatus (Darley et al., 1975). Parkinson's disease is the prototypic disease associated with *hypokinetic* dysarthria (Duffy, 2005). It has been estimated that 60-80% of Parkinson's disease patients will develop speech deficits as the disease progresses (Adams, 1994). Speech symptoms often begin with decreased loudness and progress to more severe functional limitations characterized by changes in rate, articulatory precision, and intelligibility (Yorkston et al., 2000; Trail et al., 2005).

In the seminal Mayo Clinic study of various groups of dysarthric speakers, Darley et al. (1975) described the speech characteristics of 32 patients with "parkinsonism." Of these 32 speakers, 16 were judged to use excessively short phrases and 19 were judged to produce excessively short rushes of speech separated by pauses. Twenty-five of the participants produced inappropriate silences, which was interpreted as reflecting either difficulty initiating phonation or difficulty coordinating phonation and articulation (Darley et al., 1975). All participants exhibited articulatory imprecision, and the speech rates of 28 speakers were judged to be at least "somewhat deviant." Although only four participants exhibited a "festinating" pattern (i.e., acceleration during speaking, similar to the gait pattern of many PD patients), significant variability of speech rate was exhibited by 16 speakers. The impression of festination was likely attributable to the short rushes of speech separated by pauses. Lastly, repetitions of word-initial phonemes were produced by 14 speakers (Darley et al., 1975). These speech features were assumed to result from reduced range of movements and fast repetitive movements, hence the term "hypokinetic" dysarthria (Darley et al., 1975).

## Rate Control Interventions for Dysarthric Speakers

The purpose of the following sections is to present a clinical tutorial on various evidence-based rate control interventions for dysarthric speakers. Strategies discussed represent a hierarchy from "rigid" strategies, which impose maximal rate control (e.g., pacing boards, alphabet boards), to techniques allowing for greater speech naturalness and independent rate control (e.g., rhythmic cueing). All procedures will be analyzed with respect to effectiveness in reducing speech rate, impact on intelligibility and prosody, cost, training requirements, specific alterations made to speech rate (e.g., articulation time, pause time), and other relevant dimensions.

### Pacing Boards

Helm (1979) documented the management of palilalia using a pacing board. Palilalia is a speech disorder in which a word, phrase, or sentence is repeated in an increasingly rapid manner, in some cases becoming almost unintelligible. This behavior is thought to be analogous to the festinating gait often seen in Parkinson’s disease patients; these patients have difficulty initiating walking, but walk in an increasingly rapid and uncontrolled manner once they get started (Duffy, 2005). Helm (1979) observed that many patients have no difficulty walking up and down stairs or across lines painted at intervals on the floor, presumably because these tasks substitute reactive movements for automatic movements (Helm, 1979). The participant in her study was a 54-year-old male with a "parkinsonian syndrome," exhibiting palilalia of such severity that he was essentially noncommunicative. However, this patient did not exhibit palilalia during categorical naming tasks, during which he spoke in a "one syllable at a time" manner. Therefore, Helm (1979) attempted to improve his communicative effectiveness by using a "pacing board," a 13" by 2" apparatus with eight colored segments separated by wooden dividers. While tapping his finger on the board from left to right, segment to segment, the patient spoke syllable-by-syllable "without exhibiting palilalia" (Helm, 1979).

Lang and Fishbein (1983) documented the use of a similar pacing board to remediate speech deficits. The participant was a 53-year-old male Parkinson's disease patient exhibiting rapid speech, palilalia, and frequent hesitations averaging six seconds in duration. These deficits resulted in an overall fluent speech rate that was 30% of normal rate, with a markedly reduced intelligibility. Therefore, the investigators used a pacing board to produce syllabic speech (i.e., equal duration allotted to each syllable). When using the board, the patient's rate of "coherent speech" increased to 63% of normal rate, and the disfluent behaviors were "virtually eliminated." Thus, Lang and Fishbein (1983) recommended a trial use of a pacing board before attempting other rate control strategies because of its relatively low cost, ease of use, and minimal training requirements.

## Alphabet Board Supplementation

In a study by Beukelman and Yorkston (1977), two dysarthric speakers who previously spelled out entire messages on an alphabet board were taught to use a system whereby they pointed to the first letter of each word as they spoke. The first participant (P1) was a 61-year-old male with severe speech deficits secondary to a brain stem stroke. He exhibited 10-15% intelligibility during conversational speech, and communicated primarily by spelling out entire messages on a spelling board. This yielded a rate of two to four words per minute (WPM), which impaired listeners' ability to retain sequences of letters and words (Beukelman & Yorkston, 1977). The second participant (P2) was a 17-year-old male who sustained a brain stem injury during a motor vehicle accident. He progressed through a series of communication systems including a "yes/no" signal system, a picture-word board, and a spelling board allowing him to spell out four to six words per minute. His habitual speech was nearly unintelligible, but he exhibited normal auditory comprehension, vocabulary recognition, and sentence construction abilities.

The investigators sought to design a communication system that would be more efficient than a spelling board, but just as intelligible (Beukelman & Yorkston, 1977). Thus, they devised a system consisting of oral speech supplemented by identification of the initial letter of each spoken word on an alphabet board. The listener repeated each spoken word after the speaker. When repeated incorrectly, the speaker shook his head negatively and repeated the word in question. If the word was still not comprehended after this repetition, the speaker spelled out the entire word. Instructions designed to resolve communication breakdowns included four phrases: "END OF SENTENCE," "END OF WORD," "REPEAT," "START AGAIN." The speaker pointed to these phrases whenever he felt it necessary to enhance communication efficiency.

Instructions to unfamiliar listeners explaining speaker and listener roles in the interaction were mounted on reverse side of the alphabet board. Listening judges viewed videotaped samples of the speakers producing single words and sentences, and data were obtained on speech rate (in WPM) and the percentage of words correctly identified by judges. The speaking conditions were unaided speech, aided speech, and “aided and concealed” (i.e., the portion of video monitor showing the alphabet board was hidden from the judges).

Results revealed that P1 exhibited an unaided rate of 39 WPM, an aided rate of 18 WPM, and four WPM using the original spelling method. Participant 2 produced 86 WPM unaided, 28 WPM aided, and six WPM with the spelling method. Results also revealed that single words were generally less intelligible than words produced in a sentence, suggesting that contextual cues from grammatically-complete sentences increased intelligibility (Beukelman & Yorkston, 1977). Participant 1’s sentence intelligibility was 16% unaided, 60% aided, and 19% in the “aided and concealed” condition. This suggested that merely reducing P1’s speech rate had little effect on his intelligibility. The observed increases in intelligibility were apparently due to the additional information provided to the listeners by the alphabet board.

For P2, sentence intelligibility was 33% unaided, 66% aided, and 52% “aided and concealed.” In his case, rate reduction did appear to contribute to the increased intelligibility provided by board (Beukelman & Yorkston, 1977). It should be noted that even with the use of the alphabet board, neither speaker’s intelligibility ever exceeded 75%. However, the investigators reported that both speakers were nearly 100% intelligible during conversation, presumably due to increased contextual information and their ability to resolve communication breakdowns by repeating or spelling entire words (Beukelman & Yorkston, 1977). Thus, this communication system attempted to bridge the gap between a spelling system and oral speech. It allowed the speakers to use functional speech earlier than their level of intelligibility would have permitted without the use of an external device (Beukelman & Yorkston, 1977).

In a subsequent, Crow and Enderby (1989) sought to determine whether auditory characteristics of speech are altered when dysarthric speakers point to the initial letter of a word on an alphabet board as they speak. Participants were six dysarthric speakers, one of whom exhibited hypokinetic dysarthria secondary to Parkinson's disease. Speaking tasks included a single-word task (i.e., describing 20 pictures each with one word), predictable picture description (i.e., describing six pictures each with one sentence; these pictures were designed to elicit predictable sentences), and a conversational task (i.e., one-sentence responses to common conversational sentences). Half of the stimuli were recorded while speakers used the alphabet board (i.e., the "aided" condition), and half were recorded without use of the board (i.e., the "unaided" condition).

Results of intelligibility measures yielded a main effect of task (i.e., single words were least intelligible, predictable sentences were most intelligible), and a main effect of condition (i.e., “aided” was more intelligible than “unaided”). Although statistical significance for the rate measures was not reported, mean speech rates were 101.7 WPM (unaided) and 35.2 WPM (aided). Lastly, phonetic transcriptions revealed that across speakers, twice as many target sounds were produced appropriately with the alphabet board than without it (Crow & Enderby, 1989). The authors concluded that because judges only listened to audiotapes without actually viewing the alphabet board, improvements in intelligibility were solely attributable to rate reduction. However, these reductions may have resulted from listener variables, as well as speaker variables. For example, more time was available for the listeners to process the information provided by the speaker and comprehend the message. Also, pauses inserted into sentences may have provided the listener with more well-defined word boundaries to aid in segmenting the messages. As for speaker variables, insertion of pauses, as well as increased articulation time, may have allowed more time to plan and execute the neuromotor activities necessary for speech production (Crow & Enderby, 1989).

## Visual and Auditory Feedback

Speech therapy for dysarthric speakers generally relies upon the clinician's perceptual judgments of the patient's speech production. However, it is often beneficial for patients to monitor and modify their own speech behaviors as proficiently as possible. The use of biofeedback allowing a speaker to receive immediate and continuous information about a behavior is often effective for shaping that behavior toward a desired goal. One such technique that was hypothesized to minimize a patient's dependency on the clinician involves using immediate visual feedback of speech events. The goal of this approach is for the speaker to visualize and judge the adequacy of a speech response according to predetermined criteria (Berry & Goshorn, 1983). The development of electronic visual storage units has provided further treatment options for clinicians.

In a study by Berry and Goshorn (1983), a single-subject design was used to illustrate the use of immediate oscilloscopic feedback of vocal intensity and speech rate during therapy. The participant was a 60-year-old male exhibiting severe dysarthria secondary to multiple CVAs. His speech was characterized by irregular articulatory imprecision, rapid/variable rate, harsh/breathy phonation, excessive loudness, and reduced intelligibility. A total of 40 sentences (20 high and 20 low predictability items) were used to test intelligibility prior to treatment, after five weeks of treatment, and at two weeks post-treatment. Treatment was administered twice a week during 45-minute sessions.

While reading or repeating sentences, the participant viewed an oscilloscope preset to a five-second display, and each production was channeled through an acoustic analysis system to provide immediate visual information about his speech intensity and rate (Berry & Goshorn, 1983). Prior to each sentence production by the participant, the clinician recorded a “model” production in one of four colors available for tracing. A second color line was preset at a standard distance above the first to identify an upper limit of intensity. The speaker was instructed to keep his loudness level below this line, and to speak slowly enough to “fill up” more than half of the screen's horizontal (i.e., time) display. The resulting sentence production was displayed by a third color line, with the loudness limit depicted in a fourth color. The speaker was then instructed to compare his rate and loudness to that of clinician's model. When the speaker met the duration criteria, a "good production" was stored on the oscilloscope. He then produced that same sentence several more times, and these productions were displayed in other colors. This allowed the speaker to visually compare his output with his own model in order to promote consistency (Berry & Goshorn, 1983).

Results indicated that, although statistically significant gains in intelligibility were made during treatment, the patient appeared to “regress somewhat” within two weeks. All scores were still significantly higher than baseline scores, but were also significantly lower than measures taken immediately post-treatment (Berry & Goshorn, 1983). As the authors pointed out, no specific rate reduction strategies were taught. The participant was simply instructed to “go slower,” and was given immediate visual confirmation of success or failure. He produced key words with roughly the same mean duration, but increased the length of pauses between words. In addition, this speech containing longer pauses was more intelligible. Berry and Goshorn

(1983) concluded that increasing the length of pauses either allowed more time to prepare for articulatory movements, and/or allowed listeners more processing time.

Based on results suggesting that visual biofeedback may be useful in treating prosodic disorders (Berry & Goshorn, 1983), LeDorze, Dionne, Ryalls, Julien, and Ouellet (1992) investigated the use of computer-assisted auditory and visual feedback to treat such deficits. They used a single-subject design with a 74-year-old woman exhibiting hypokinetic dysarthria secondary to Parkinson's disease. Her speech was characterized by reduced pitch range, inappropriate pitch level, and rapid rate. This resulted in poor articulation and speech that was perceived as "moderately unintelligible" (LeDorze et al., 1992). Baseline measures of three behaviors (i.e., intonation, mean fundamental frequency, and rate) were taken throughout the study, and the behaviors were treated sequentially. These measures were obtained with a computerized speech analysis system that provided on-line measures of acoustic parameters.

During treatment, the patient produced various words, phrases, and sentences. She received visual and auditory feedback on the computer screen following each production; in addition, feedback pertaining to the adequacy of each production was provided the clinician. By using the computerized system, the clinician was able to model and record the desired behavior in the top half of screen, while the patient's speech productions were recorded in bottom half for comparison; audio playback of the productions was also possible with this apparatus. Traditional therapy techniques that facilitated production of each target behavior were also used (e.g., increasing expiratory muscle force). Two to three 60-minute sessions were conducted each week for nine weeks, and treatment objectives were gradually increased until pre-specified criteria were met (LeDorze et al., 1992).

Results indicated that speech rate for declarative sentences ranged from 3.8-4.7 SPS during the extended baseline. Consequently, the criterion for rate was fixed at 3.8 SPS (i.e., two standard deviations below the mean of 4.3 SPS during baseline). After three sessions, there was reportedly a "substantial decrease" in rate. Follow-up measures taken ten weeks post-therapy revealed a rate of 3.9 SPS, which was slightly faster than results obtained during treatment, but slower than the mean rate recorded prior to therapy. Additionally, there was a statistically significant improvement in intelligibility from 86% (baseline) to 96% (post-therapy). The authors concluded that the treatment led to improvement when attention was given to a specific behavior. There were 25 sessions in total, and measurable improvement was observed after ten weeks, similar to results reported by Caligiuri and Murry (1983). On-line measures were used to guide treatment, as well as document its effectiveness. Results suggested that immediate visual and auditory feedback may be effective in improving prosody (LeDorze et al., 1992). As in the Berry and Goshorn (1983) study, however, the relative contributions of the visual and auditory feedback were not demonstrated.

## Cueing/Pacing Strategies

Yorkston and Beukelman (1981) evaluated several treatment options for dysarthric speakers designed to improve intelligibility and prosody. One such technique was rhythmic cueing, a "behavioral" rate control method often used as a "transition" between rigid rate control techniques (e.g., pacing board) and self-monitoring of speech rate (Yorkston & Beukelman, 1981). By pointing to words to be read by the speaker, the clinician paced the reading by imposing a slow rate with "appropriate" pausing and phrasing. This resulted in more natural prosody than the "one word at a time" quality of the pacing board, which had been shown to allot equal duration to all syllables and yield relatively long interword pause times (Helm, 1979; Lang

& Fishbein, 1983). To facilitate natural prosody, the clinician cued stressed syllables more slowly than unstressed syllables, and gave greater emphasis to more "prominent" words (Yorkston & Beukelman, 1981).

Participants were instructed to follow the imposed rhythm, and were permitted to lag behind but not "get ahead" of the clinician. As speakers became more proficient at controlling their rates, cueing gestures were "faded by gradually diminishing and then eliminating them" (Yorkston & Beukelman, 1981). One participant, for example, read at a rate of 137 WPM prior to therapy, well below the normal rate of 160-170 WPM for adults (Fairbanks, 1960). However, the investigators felt that this rate was still too rapid for this patient's speech production capabilities, as his speech was characterized by limited articulatory movement and reduced intelligibility. Therefore, rhythmic cueing was selected to reduce his speech rate. After four weeks of treatment, the participant maintained a rate of 80 WPM, and achieved articulatory targets adequately. Following seven months of treatment, his speaking rate increased to 134 WPM, yielding a 99% intelligibility score (Yorkston & Beukelman, 1981).

A computerized version of this cueing strategy was utilized by Yorkston, Hammen, Beukelman and Traynor (1990). The speaking rates of four speakers with hypokinetic dysarthria and four normal speakers were reduced to 60% and 80% of their habitual rates using four different pacing strategies. The effects of these various strategies on sentence intelligibility and speech naturalness were examined (Yorkston et al., 1990). For the speech naturalness measure, a sample from each reading passage was judged for intonation, voice quality, rate, rhythm, and intensity using a seven-point interval scale (i.e., 1 = most natural, 7 = least natural) (Darley et al., 1975). Reading rates were controlled using a computer software program called PACER, which allowed the clinician to enter reading passages into the computer and select desired target rates. Each participant read under nine different conditions (i.e., habitual rate and four rate control strategies at two rates each).

Presentation style (i.e., additive and cued) and timing relationships (i.e., metered and rhythmic) were manipulated. *Additive pacing*, considered the most rigid style, involved presentation of the reading passage on the computer screen one word at a time. *Cued pacing*, a less rigid rate control method, involved the entire passage appearing on the screen, with a cursor automatically cueing each word according to the target rate selected by the clinician. During the *metered pacing* conditions, each word was given equal duration (similar to metronome pacing). In contrast, *rhythmic pacing* more closely simulated "natural" speech, as stressed syllables more were allotted more time than unstressed syllables (similar to what clinicians typically do during "finger-cueing") (Yorkston & Beukelman, 1981).

During the *Additive-Metered* Condition (AM), the reading passage was presented on the screen one word at a time, and each word was allotted equal duration. In the *Additive-Rhythmic* Condition (AR), timing patterns simulated normal speech, as the computer program assigned a relative durational value to each word by estimating the number of syllables in a word. In the *Cued-Metered* Condition (CM), the entire reading passage was presented on the screen. Activation of a switch initiated underlining of each word with equal duration at a rate selected by examiner. Lastly, the *Cued-Rhythmic* Condition (CR) was similar to AR, except that the entire passage was presented on the computer screen (Yorkston et al., 1990).

Results obtained included mean habitual rates of 201 WPM for the dysarthric speakers and 190 WPM for the control group. Under the rate control conditions, target rates were achieved within 10%. Thus, PACER effectively controlled speech rate for both groups of speakers in a relatively short period of time (Yorkston, Hammen, Beukelman, & Traynor, 1990). Results revealed that when the dysarthric speakers reduced their speech rate to 60% of their habitual rates, their intelligibility increased from 60.7% to 81.2%. Next, the differential effects of the various rate control strategies on intelligibility were assessed. The metered conditions produced higher mean sentence intelligibility scores for both groups of participants than the rhythmic conditions (Yorkston et al., 1990). Specifically, the pacing strategy that placed the entire reading passage on the computer screen and allotted the same amount of time for each word (i.e., Cued-Metered) produced the greatest intelligibility.

In addition, the mean naturalness ratings for the control group decreased from 1.8 (at habitual rate) to 2.7 (at 60% of habitual rate). Ratings for the dysarthric speakers decreased only slightly from 4.3 (habitual rate) to 4.5 (60% rate). This suggested that the habitual speech of the dysarthric speakers was perceived as quite unnatural, although rate reduction did not result in substantial further deterioration. For both groups, the metered strategies yielded the lowest naturalness scores, but this trend was most marked for the control speakers. Interestingly, the rhythmic conditions resulted in almost identical naturalness scores as habitual rate for dysarthric speakers (Yorkston et al., 1990).

## Delayed Auditory Feedback

The following sections will examine the documented effects of an alternative rate control intervention known as delayed auditory feedback (DAF). Essentially, this technique involves delaying the auditory feedback of the person's speech a fraction of a second, which requires him or her to prolong each syllable until the feedback "catches up" to the speech production. Ideally, this induces a relatively slow, fluent speech pattern characterized by prolonged syllable nuclei (i.e., vowels), smooth transitions between syllables, and relatively stable syllable duration

(Goldiamond, 1965; Ingham, 1984). Evidence from a several published reports, as well as anecdotal clinical evidence, suggests that DAF offers several advantages as a method of rate reduction for dysarthric speakers (Yorkston et al., 2000). When used effectively by adequately trained clinicians with appropriate patients, it provides easily adjustable and often dramatic reductions in speech rate.

Portable DAF units also allow for home practice, as well as independent "self-therapy" once a patient has become proficient at the task. For example, the auditory feedback may be faded by either gradually reducing the delay interval or gradually reducing the loudness of the auditory feedback. This could provide a systematic method for reducing the speaker's reliance on the device, although further research documenting successful fading of DAF with dysarthric speakers is needed. Lastly, DAF units are also used effectively as prosthetic devices (e.g., Hanson & Metter, 1980; 1983) by those who are simply unable to transfer therapy gains to "outside" speaking situations due to the severity of their neuromotor impairments, cognitive limitations, and/or limited access to a speech-language pathologist.

In an early study, Singh and Schlanger (1969) examined the effects of DAF on speech duration and intensity during production of sentences. The speakers exhibited various types of dysarthria, with one exhibiting hypokinetic dysarthria secondary to Parkinson’s disease. All speakers read or repeated 12 sentences, and a delay interval of 180 ms was used due to its documented effects on the speech of normal speakers (Black, 1951; Lee, 1951). Each speaker produced the sentences without DAF, and then again with DAF. Results revealed that the use of DAF resulted in significantly longer durations (i.e., slower rates), as well as significantly increased voice intensity.

Downie, Low, and Lindsay (1981) documented the use of DAF by two Parkinson's disease patients. P1 exhibited speech characterized by poor intelligibility, frequent hesitations, syllable repetitions, short rushes of speech, and excessive rate. After other interventions were shown to be ineffective, a trial with 50 ms DAF resulted in a "dramatic improvement" in intelligibility and reduced speech rate. After three months of "home use," however, the original speech pattern re-emerged. Following one year of disuse of the DAF unit, the patient obtained "intermittent benefit" with a delay setting of 150 to 200 ms. The authors hypothesized that deterioration of motor functioning due to the disease necessitated a substantial increase in delay interval (Downie et al., 1981).

P2 also exhibited accelerating speech with weak intensity and poor intelligibility. With the use of 50 ms DAF, his speech became slower, louder, and "completely fluent." This patient continued to wear the portable DAF unit for two years, with persistent improvement in intelligibility whenever the unit was in use (Downie et al., 1981). Thus, DAF was judged to be applicable primarily to cases of festinating speech, an accelerating speech pattern reminiscent of the gait of many PD patients. The impact upon the speech of the two patients was reportedly "dramatic," although the authors noted that there was no indication that DAF produced any lasting effects on speech rate when the unit was not in use (i.e., no carry-over). Thus, they compared the DAF unit to "a pair of spectacles," concluding that it must be used continuously to be effective (Downie et al., 1981). As one of the first documented studies using DAF with PD, this report suggested clinically significant effects on speech rate and intelligibility. Essentially a case study, it provided some limited evidence of the potential benefits of DAF, while serving to generate further interest in its use with PD patients.

Hanson and Metter (1980) used a portable DAF unit to reduce speech rate and improve intelligibility in a patient with progressive supranuclear palsy (PSP), a progressive neurological disorder often associated with "parkinsonian" symptoms (Yorkston et al., 2000; Duffy, 2005). This patient's speech was characterized by rapid acceleration, weak intensity, limited pitch range, imprecise consonant articulation, and poor intelligibility. After eight months of unsuccessful speech therapy focusing on rate reduction and self-monitoring of speech, DAF was observed to effectively reduce his rate and increase his intensity. Subsequently, he began to wear a portable DAF unit as permanent speech prosthesis (Hanson & Metter, 1980).

Measurements of rate, intensity, and intelligibility were taken both with and without DAF. Reading was selected as the speech task in order to provide a more uniform speech sample for series measurements (Hanson & Metter, 1980). During each of the two recording sessions, the participant read a passage ten times, with DAF being introduced during trials 4 and 8 only. A delay interval of 100 ms was selected because of its "positive effect" on the patient's speech (Hanson & Metter, 1980). Speech measures were obtained at beginning of therapy and three months later, following daily "home use" of the DAF unit. Reading rates obtained were 255 WPM pre-therapy and 311 WPM post-therapy without DAF, and 116 WPM pre-therapy and 104 WPM post-therapy with DAF. Thus, DAF yielded significantly lower rates than the normative value of 177.6 WPM (Canter, 1963). During all measurements, both with and without DAF, speech intensity was within the normal range of 72.0 dB to 85.9 dB SPL (Canter, 1963). Intelligibility scores were 5.75 pre-therapy and 6.88 post-therapy without DAF (on a scale from 1 to 7), and 1.00 with DAF (both pre- and post-therapy).

Additionally, the patient's family stated that his speech was much improved when using DAF, and that he exhibited greater willingness to participate in conversations (Hanson & Metter, 1980). As a supplement to the objective data provided, family members' comments confirmed the clinical significance of treatment gains. This is an example of "subjective evaluation," a type of therapeutic criterion sometimes used to assess whether treatment has led to qualitative differences in how others view the speaker (Christensen, 1988).

Following prosthetic use of DAF with a dysarthric speaker with PSP, Hanson and Metter (1983) assessed its effects on the speech of two Parkinson’s disease patients. Patient A was a 58-year-old male with speech characterized by poor intelligibility, weak intensity, rapid rate, and reduced variability of pitch and loudness. He participated in speech therapy using various rate control strategies for nine months. Although some success in the clinic was noted, no carry-over was observed. Patient B was a 56-year-old woman who presented rapid speech rate, limited pitch variability, weak intensity, imprecise consonants, and mildly impaired intelligibility (Hanson & Metter, 1983). Measures of speech rate, intensity, and intelligibility were taken on four occasions (i.e., during baseline and at one-month intervals thereafter for three months). Both patients wore portable DAF units "as needed" for three months. A delay interval of 150 ms was selected because it reportedly produced the greatest degree of rate reduction with the least disruption of “speech flow," and because both patients tolerated it well (Hanson & Metter, 1983).

During all four recordings, Patient A's habitual reading rate exceeded the normal range of 140-219 WPM (Canter, 1963), whereas DAF reduced his rate slightly below the normal range. However, home use of the unit did not result in any noticeable carry-over of treatment gains. During conversation, this patient’s speech rate without DAF could not be measured due to poor differentiation of individual words. However, his mean conversational rate with DAF was within the normative range of 150-250 WPM (Goldman-Eisler, 1968). The patient's speech intensity increased significantly with DAF, and (most importantly) his intelligibility was significantly improved. Judged on a seven-point scale, his intelligibility during conversation improved from 6.50 without DAF to 3.00 with DAF (Hanson & Metter, 1983). The use of DAF reduced Patient B 's reading rate from 183.3 WPM, to 137 WPM, and reduced her conversational rate from 238.8 WPM to 166.8 WPM. Her speech intensity was significantly higher with DAF, but only during reading. Lastly, her mean intelligibility rating for reading improved from 2.25 without DAF to 1.50 with DAF, and from 3.50 without DAF to 2.25 with DAF during conversation (Hanson & Metter, 1983).

An acoustic analysis of selected phrases from the reading passages revealed that both speakers increased duration of the speech segments (i.e., articulation time) as well as between-segment pauses (i.e., pause time). These increases were relatively proportional (Hanson & Metter, 1983). This analysis provided additional information about specific rate changes resulting from use of DAF; this was the first study to demonstrate such acoustic changes associated with use of DAF. Such information has important clinical implications, as the relative duration of articulation time and pause time play a key role in perceived speech rate, as well as speech naturalness (Tjaden, 2000; Yorkston et al., 1988). In general, significant gains were made by both patients, particularly in speech rate and intelligibility; however, this did not seem to generalize to their speech without DAF. Therefore, the authors recommended the DAF unit as a "compensatory speech aid" to be used with or without other forms of therapy (Hanson & Metter, 1983).

Yorkston, Beukelman, and Bell (1988) documented the use of DAF with a 72-year-old male PD disease patient whose habitual reading rate was 262 WPM (i.e., 138% of normal rate), with 67% intelligibility. The investigators chose DAF based on the prediction that, if effective, it would require the least amount of training (Yorkston et al., 1988). The patient's reading rate was reduced as the delay interval was increased from 0 ms to 100 ms, and again from 100 ms to 150 ms.; no further rate reduction was observed when the interval was increased to 200 ms. This procedure confirmed the effects of DAF and allowed selection of the delay that produced maximal rate reduction (Yorkston et al., 1988). At 150 ms, the speaker's reading rate was 135 WPM, with 97% intelligibility. The short rushes of speech were reportedly eliminated, and breath group patterns and intonational contours were preserved.

An acoustic analysis revealed that DAF increased both articulation time and pause time; this may have been responsible for the preserved naturalness of speech (Yorkston et al., 1988). These findings were consistent with those of Hanson and Metter (1983). However, the authors reported that DAF was not as effective during conversational speech. Therefore, to bring conversational speech under greater control of DAF, the investigators trained the speaker to allow DAF to become a more effective "speech pacer." Specifically, he was instructed to prolong the initial word of each utterance with a "relatively strong intensity," speak in full phrases, and speak slowly enough to avoid “overdriving" the DAF unit (Yorkston et al., 1988).

This was the first report to graphically depict the effects of gradually increasing delay interval on speech rate. Doing so helps to illustrate the process of selecting the optimal delay interval for a particular speaker. For example, the fact that speech rate did not decrease when the delay interval was increased from 150 ms to 200 ms suggested that the speaker may not have been precisely “matching” the delayed signal (i.e., the echo). Such information provides valuable clinical insight into exactly what individuals are doing (or not doing) while speaking with DAF. The authors offered some useful suggestions for training speakers to use DAF more effectively, including not speaking rapidly enough to "overdrive" the DAF unit (Yorkston et al., 1988). This suggestion alluded to the need for speakers to match the delay signal to achieve maximal rate reduction. The authors also acknowledged that some patients require overt instruction to effectively reduce their rates with DAF (Yorkston et al., 1988).

In an innovative study, Adams (1994) assessed the effects of DAF using phonetic and acoustic analyses, as opposed to clinician impressions (e.g., Downie et al., 1981), rating scales (e.g., Hanson & Metter, 1983), or global measures of severity (e.g., Yorkston et al., 1988). The participant was a 78-year-old male with hypokinetic dysarthria secondary to PSP. His conversational speech rate was 375 WPM (without interphrase pauses), with 54% intelligibility (Adams, 1994). Speech tasks included isolated words, short conversational samples, and words embedded in carrier phrases produced three times in succession. This repetition task permitted a more complete evaluation of “accelerating speech.” In addition, the speaker produced two multi-syllabic utterances three times consecutively (e.g., "sapapple-sapapple-sapapple"). He produced all stimuli both with and without 80 ms DAF; however, the author did not explain how or why this delay was selected, or how long it took to find this "optimal delay."

Results revealed that the speaker's conversational rate was reduced 150-200 WPM with DAF, within the normative range (Goldman-Eisler, 1968); sentence intelligibility increased from to 95% with DAF. Phonetic errors made during baseline (e.g., cluster reduction) were "virtually eliminated" by the use of DAF (Adams, 1994). Spectrographic analysis revealed that the speaker's poor intelligibility was not simply due to the rapid rate of speech, but rather the reduction in or absence of specific acoustic features. The use of DAF restored most of the expected phonetic and acoustic features, resulting in greatly improved intelligibility (Adams, 1994). In general, DAF was shown to be a practical, effective, and "relatively long-term solution" for this individual (although no follow-up data were reported).

## Summary and Clinical Implications

To summarize, rigid rate control techniques such as pacing boards and alphabet boards have been shown to be effective in reducing rate and improving intelligibility in cases of severe dysarthria (Beukelman & Yorkston, 1977; Helm, 1979; Lang & Fishbein, 1983; Crow & Enderby, 1989). These techniques offer relatively little expense, ease of use, minimal training requirements, and the option of home practice. Alphabet board supplementation offers the additional advantage of visual cues to aid the listener in comprehension of the message (Beukelman & Yorkston, 1977; Hustad, Jones, & Dailey, 2003; Hustad & Garcia, 2005). However, these external devices may be considered cosmetically unacceptable, require manual dexterity, may require normal vision and adequate spelling ability, and may result in adaptation or overlearning of the required movement (Yorkston et al., 1988). These strategies also tend to disrupt prosody by imposing a "one word at a time" speech pattern with pauses between words. In general, they are often effective when other interventions fail, allowing severely dysarthric patients to use oral speech earlier in treatment than would have otherwise been possible (Beukelman & Yorkston, 1977).

Rate control strategies that preserve prosody (e.g., oscilloscopic feedback, computerized systems, pacing) require significantly more training, relatively intact cognitive abilities, and ample time to master new motor skills (Yorkston et al., 1988). This may pose a difficulty for sub-groups of Parkinson's disease patients who exhibit dementia (Levin, Tomer, & Rey, 1992) or other cognitive deficits (Saint-Cyr, Taylor, & Lang, 1988). For appropriate speakers, visual and/or auditory feedback may be useful for training these individuals to monitor and modify their own speech behaviors within nine or ten weeks of treatment (Caligiuri & Murry, 1983; LeDorze et al., 1992). In addition to the relatively high cost of the systems discussed, however, the do not allow for gradual fading of the visual feedback. This may limit the transfer of gains acquired in the clinic to "real world" speaking situations. Also, the relative contributions of visual and auditory feedback were not clearly demonstrated in the studies discussed (Berry & Goshorn, 1983; Caligiuri & Murry, 1983; LeDorze et al., 1992).

Other "behavioral" rate control methods such as cueing and pacing strategies have been recommended as a transition between rigid techniques and self-monitoring of speech rate (Yorkston & Beukelman, 1981). These strategies typically result in more natural prosody and re-introduce normal rhythmic elements into the patient's speech pattern. For example, Yorkston and Beukelman (1981) gradually increased the rate of one patient’s speech from 80 WPM to 134 WPM while maintaining 99% intelligibility (Yorkston & Beukelman, 1981). However, the seven months of treatment needed to obtain such dramatic gains underscores the relatively taxing training requirements of such behavioral interventions. Computerized pacing programs offer the ability to select precise speaking rates (not possible with "finger-pacing"), as well as the added benefits of home practice (provided that the patient has access to a computer). The PACER program has been shown to effectively pace speaking rate within a relatively short training period (Yorkston et al., 1990).

It is widely believed that for many dysarthric speakers, intelligibility must take priority over speech rate and naturalness. For example, Yorkston et al. (1988) recommended that when intelligibility reaches 90%, improvements in rate and prosody should be attempted. The target rate should continue to increase as long as intelligibility is maintained. Thus, the primary goal for clinicians should be to use the least intrusive rate control technique that provides adequate rate reduction, while maximizing intelligibility and speech naturalness. If substantial improvement is not observed, however, rate control may not be appropriate for that individual. In such cases, other management approaches should be considered (Yorkston et al., 2000).

Additionally, findings from a number of published studies confirmed clinical impressions of DAF as an effective rate control strategy for some speakers with hypokinetic dysarthria (e.g., Downie et al., 1981; Adams, 1994). Improvements in rate and intelligibility were evidently related to increased articulation time, as well as increased pause time (Yorkston et al., 1988; Adams, 1994). Studies have generally shown DAF to be most effective in reducing reading rate, as opposed to spontaneous speech rate (e.g., Yorkston et al., 1988). This may be due to the reduced linguistic and motor demands of reading (Norris, Healey, Hoffman, Blanchet, Kaufman & Scott-Trautman, 1998), and is consistent with findings of the effects of DAF on persons who stutter (Ingham, 1984; Bloodstein, 1995).

Delay intervals ranging from 50 ms (e.g., Downie et al., 1981) to 150 ms (e.g., Hanson & Metter, 1983; Brendel, Lowit, & Howell, 2004) have been used effectively with dysarthric speakers, whereas intervals exceeding 150 ms were reported to yield no further gains in rate or intelligibility (Yorkston et al., 1988). In fact, such delays intervals have reportedly produced "disastrous" effects on the speech of some speakers (Rosenbek et al., 1978). Such reactions to relatively long delay times are commonly observed during clinical use of DAF, and likely result from improper matching of the delayed signal. For example, a delay interval of 150 ms produces a relatively long time lag between production of a syllable and its perception. Unless the speaker continues to prolong the syllable until the delayed auditory signal is perceived, this signal is not completely "canceled out." This often results in a salient and potentially aversive "echo," which may limit the rate reduction benefits of DAF, and may actually *elicit* disfluencies (e.g., syllable repetitions). Such behaviors have been observed in persons who stutter (Goldiamond, 1965), dysarthric speakers (Rosenbek et al., 1978; Dagenais et al., 1998), as well as unimpaired speakers (Black, 1951; Lee, 1951; Soderberg, 1968).

To facilitate optimal use of DAF, therefore, clinicians should provide instruction, modeling, and feedback. As stated above, DAF has been primarily used with dysarthric speakers as a prosthetic device, with carry-over of speech gains rarely expected. However, it may be difficult for a patient with a neurological disease to generalize a behavior if he or she does not understand what the specific target behavior is. In other words, simply instructing someone to wear a DAF unit and "begin talking" does not provide any guidelines for properly matching the delayed signal in order to obtain maximal speech rate reduction. As highlighted by Duffy (2005), overt instruction improves performance, as most patients do not simply improve by talking. The ability to alter speech with instruction is a positive prognostic indicator, although this assumption has not been tested formally (Duffy, 2005). Feedback is essential to motor learning, especially in early stages, and should be immediate and precise relative to the treatment goals (Schmidt & Lee, 1999; Yorkston et al., 1988). Such feedback should be specific, and can be instrumental or administered by the clinician. Rosenbek and LaPointe (1978) further asserted that the clinician should be as active in DAF training as in any other form of treatment, as carry-over can only be achieved if the clinician provides feedback regarding the speaker's performance.

## Implications for Future Research

As mentioned throughout this tutorial, some of the treatment studies discussed presented methodological limitations. Future studies examining the effects of rate control procedures on dysarthric speech would benefit from attention to several important design principles. First, clinical procedures (i.e., length of treatment, clinician instructions, fading procedures, dependent measures, etc.) should be described in a way that allows for accurate replication by clinicians, as well as other researchers. For example, measures such as syllables per second, percentage of intelligible words, and percentage of disfluency are more objective than rating scales. The use of objective measures facilitates comparison between various studies, as well as replication of the clinical procedures.

Secondly, speech tasks used for pre- and post-treatment comparisons of speech parameters should be similar to tasks used during treatment. This allows for a more accurate demonstration of therapeutic gains, as different tasks (e.g., reading, conversation, picture description, etc.) vary considerably in terms of linguistic, cognitive, and motor demands imposed upon the speaker (Norris et al., 1998). Such variables should be given consideration when providing treatment for individuals with neuromotor impairments such as Parkinson's disease (Rousseau & Watts, 2002).

Lastly, studies using experimental single-subjects designs are needed in order to *clearly* demonstrate the controlling effects of specific treatment variables on speech behaviors (Kadzin, 1982; Ingham, 1984). For example, A-B-A-B and alternating-treatments designs are particularly well-suited for evaluating the relative effectiveness of two or more treatments, or treatment versus "no treatment" conditions (Barlow & Hersen, 1984). Single-subject designs can also be used to provide follow-up data by simply adding an extended "no treatment" phase after the final treatment phase, or by taking periodic generalization probes. Also, by including a "no treatment" condition during each treatment session, a "running baseline" is available throughout the study. This feature is useful for measuring generalization of treatment gains (i.e., "carry-over") across time.

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